

Short thesis of Doctoral (Ph.D.) Dissertation

Development of weed control technologies for alternative crop species

Csaba Juhász

PhD candidate

Supervisor:

Dr. László Zsombik Ph.D.

Scientific advisor



UNIVERSITY OF DEBRECEN

**Kálmán Kerpely Doctoral School of Crop Production and
Horticultural Sciences**

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1. THE ANTECEDENTS AND THE OBJECTIVES OF THE DOCTORAL DISSERTATION

In Hungary, as well as worldwide, white lupine (*Lupinus albus* L.), common vetch (*Vicia sativa* L.), hairy vetch (*Vicia villosa* Roth.) and buckwheat (*Fagopyrum esculentum* Moench) are among the crops that can be grown with a small ecological footprint. In Hungary, these crop species may primarily gain prominence in the context of greening measures. Greening has been mandatory in Hungary as part of the reform of the Common Agricultural Policy (CAP) introduced in 2013 (Mizik, 2019). Due to the Common Agricultural Policy, the role of green manure crops has become more valued both in Hungary and in Europe. In earlier times, little attention was paid to the damage inflicted on the soil after cultivation; the soil was regarded primarily from the perspective of the success of crop production. This period is referred to as the era of crop-centred cultivation (Mikóházi, 2010).

Due to their specific traits, the above-mentioned plant species can also be cultivated for a number of additional purposes. In the cultivation of alternative crops, both the cost–benefit ratio and the technological elements may differ from those customary in conventional large-scale crop production (Söjtöri, 2019), and the introduction of these crops into production may lead to economic growth in rural areas, a reduction in agricultural expenditures, and an improvement in the economic viability of farmers (Brummer et al., 2000; De La Torre Ugarte et al., 2003).

So-called minor crops currently play a lesser role in Hungary compared with major crops due to their relatively small production scale, however, their importance may increase in the future as sustainable, environmentally friendly farming systems advance. In the near and distant future, the global cropping structure may generate an increasing demand for the cultivation of alternative crops, which in turn may lead to a worldwide rise in the demand for seed of these alternative species.

Both the quantity and quality of seed yield can be greatly threatened by the weed species occurring in a given area. Through their seeds and plant residues, weeds can decrease the purity and quality of the harvested seed. Weed seeds are undesirable components of the harvested yield, similarly to empty and damaged seeds (Sharma et al., 2023). For the above-mentioned crops, the chemical weed control technology is less well developed in terms of its details. Both in Hungary and internationally, the topic is covered or even mentioned by only a few literature sources. The absence of suitable plant

protection technologies can lead to uncertainty in practical farming, hence, the successful development of plant protection technologies for smaller, less extensively researched crops may be crucial in the future. In the case of minor crops, plant protection strategies that are well-developed and have proven efficacy serve as important decision support role for farmers.

The main objectives of my research were as follows:

- To examine and validate pre- and post-emergence chemical weed control options in lupine, common vetch, hairy vetch and buckwheat.
- Assessment of the phytotoxic effects of herbicides on crop plants using visual phytotoxicity scoring and handheld NDVI measurements, as well as analysis of the relationship between the two methods using Spearman's rank correlation.
- Assessment of the effects of herbicide treatments on the foreign matter content of the harvested seed yield.
- Presentation of the research findings, particularly those related to herbicide selectivity, to scientific and professional audiences, and communication of the conclusions to practitioners.
- Comparison of the phytotoxicity of active ingredients used internationally in the investigated crops with the results of our own experiments conducted under Hungarian cultivation and ecological conditions.

2. MATERIAL AND METHODS

The field experiments were established at the Nyíregyháza Research Institute of the Institutes for Agricultural Research and Educational Farm, University of Debrecen (Szabolcs-Szatmár-Bereg County). The location of the field small-plot experiments was changed annually in order to prevent plant diseases and comply with crop rotation requirements. In 2022, the experiments were established on sandy soil with medium humus content, whereas in 2023 and 2024 they were set up on sandy loam soils with good humus supply. In 2025, the experiments were carried out on sandy soil with a high humus content. In 2025, the hairy vetch herbicide experiment was carried out at a different site from the other experimental areas, on sandy soil with a medium humus content, because its sowing date differed from that of the other crops.

Monthly mean temperatures increased up to July–August, and there were considerable differences between the years in some months. Early spring temperatures (March and April) were higher in 2024 than in the previous years. In 2023 and 2025, July was cooler compared with the other two years (*Figure 1*). However, there were considerable differences in precipitation. In 2022, drought affected almost the whole country, and the distribution of rainfall was very unfavourable only small amounts of rain fell in late spring (May) and in the summer months. In this month, white lupine was in the pre-flowering stage, the dry weather resulted in a large number of sterile flowers, and the plants also remained short. In May, common vetch produced a substantial increase in green biomass; however, due to the lack of precipitation, this growth slowed down later. In 2023, precipitation arrived in larger amounts and with a more even distribution. By mid-June, lupine had already started flowering, while by the end of the month, common vetch and buckwheat plants had also begun flowering. In 2024, an outstandingly high amount of precipitation was recorded in June. In 2025, the highest amount of precipitation was measured in March.

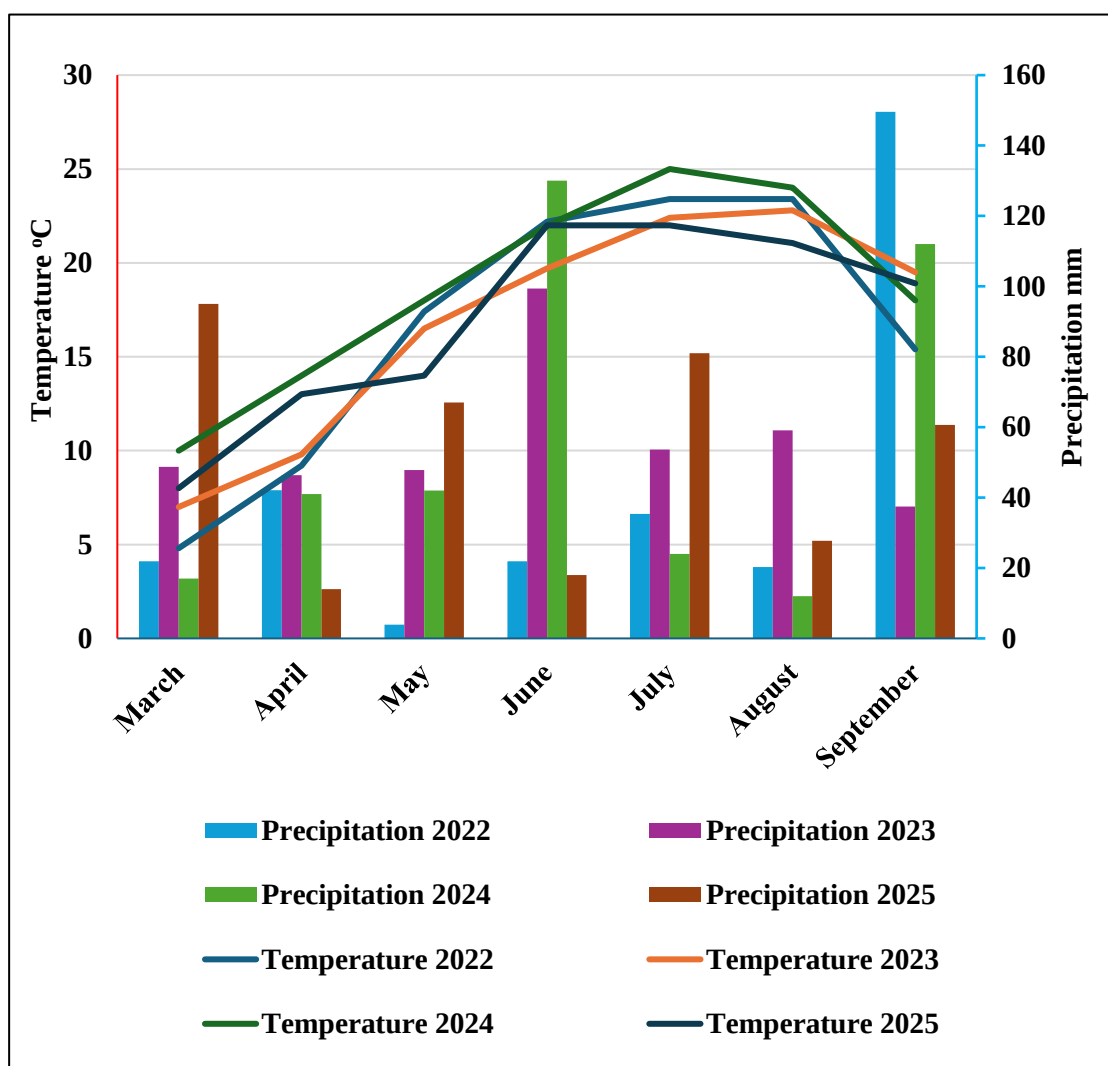


Figure 1. Precipitation (mm) and monthly mean temperature (°C) during the growing seasons of the experimental years (2022, 2023, 2024 and 2025)

The plant species and cultivars tested in the experiment, as well as the data on previous crops, plot sizes and sowing dates are presented in *Table 1*. In each experimental year, a randomized complete block design with four replications was used. The agrotechnical implementation of the experiments was carried out according to the cultivation technology widely used in practice.

Table 1. Conditions of the experiments

Plant species; cultivar	Previous crop	Plot size	Sowing date
2022			
Sweet white lupine (<i>Lupinus albus</i> L.); 'Nelly'	Corn (<i>Zea mays</i> L.)	1.7 x 5 m	7 April
Common vetch (<i>Vicia sativa</i> L.); 'Emma'	"	"	"
2023			
Sweet white lupine (<i>Lupinus albus</i> L.); 'Nelly'	Sunflower (<i>Helianthus annuus</i> L.)	2 x 10 m	24 April
Tavaszi bükköny (<i>Vicia sativa</i> L.); 'Emma'	"	"	24 April
Buckwheat (<i>Fagopyrum esculentum</i> Moench.); 'Hajnalka'	"	"	24 May
2024			
Sweet white lupine (<i>Lupinus albus</i> L.); 'Nelly'	Corn (<i>Zea mays</i> L.)	1.7 x 5 m	18 March
Common vetch (<i>Vicia sativa</i> L.); 'Emma'	"	"	18 March
Buckwheat (<i>Fagopyrum esculentum</i> Moench.); 'Hajnalka'	"	"	08 May
Hairy vetch (<i>Vicia villosa</i> Roth.); 'Hungvillosa'	"	"	04 March
Hairy vetch (<i>Vicia villosa</i> Roth.); 'Hungvillosa'	"	"	17 October
2025			
Sweet white lupine (<i>Lupinus albus</i> L.); 'Nelly'	Corn (<i>Zea mays</i> L.)	1.7 x 5 m	09 April
Common vetch (<i>Vicia sativa</i> L.); 'Emma'	"	"	09 April
Buckwheat (<i>Fagopyrum esculentum</i> Moench.); 'Hajnalka'	"	"	28 May

For herbicide application in 2022, 2024 and 2025, a Stihl SG 71 back sprayer was used, with a spray volume of 300 L ha⁻¹. In the 2023 experimental year, the active substances were applied using a Szolnok PP01HT small-plot sprayer, with a spray volume of 275 L ha⁻¹.

In the 2022 experimental year, seven pre-emergence treatments were applied in lupine in the days following sowing, while one treatment, imazamox, was applied post-emergence 32 days after sowing. At this time, the crop stand was at the BBCH 39 phenological stage, corresponding to 11 or more developed leaves (*Table 2*). After sowing, 12 mm of precipitation was recorded.

In the 2023 experimental year, our field research was conducted in collaboration with the Plant and Soil Protection Department of the Government Office of Szabolcs-Szatmár-Bereg County. As a result of this collaboration, the range of active ingredients applied was substantially expanded. The white lupine and common vetch experiments included pre-emergence treatments, however, no precipitation was received in the experimental area in the two weeks following application, and therefore the affected treatments were excluded from the experiment. Precipitation plays a critical role in the efficacy of pre-emergence herbicides, as it influences their activation. Adequate and timely precipitation is required for optimal herbicide efficacy (DiTomaso, 1997). In lupine, the standard post-emergence treatments were carried out on the 30th day after sowing, at the BBCH 39 phenological stage. The late post-emergence treatments, involving the application of halauxifen-methyl and halauxifen-methyl + picloram, were applied on the 39th day after sowing, also at BBCH 39. However, at this time, the crop stand had a more developed canopy compared with the timing of the standard post-emergence treatment, with approximately 4–6 additional leaves.

In the 2024 experimental year, pre-emergence treatments in lupine were applied 3 days after sowing. In the two weeks following the treatments, 12.3 mm of precipitation was recorded. The standard post-emergence active ingredients were applied 30 days after sowing, at the BBCH 39 phenological stage, while the late post-emergence treatments, halauxifen-methyl and halauxifen-methyl + picloram, were applied 42 days after sowing, also at BBCH 39. Despite the 12-day interval between the two treatment timings, the number of leaves in the crop stand increased only slightly.

In the 2025 growing season, pre-emergence treatments were applied on the day of sowing, followed by 12.6 mm of precipitation over the next two weeks. Post-emergence treatments were applied 36 days after sowing, at BBCH 39.

Table 2. Lupine experiment treatment codes, active substances, time of application, doses of active substances and herbicide application rate

(Nyíregyháza, 2022-2025)

Active substances	Treatment codes				Active substance dose	Herbicide application rate
	2022	2023	2024	2025		
Pre-emergence treatments						
Flumioxazin	K1	-	K1	*	30 g ha ⁻¹	0.06 kg ha ⁻¹
Pendimethalin	K2	-	K2	*	2275 g ha ⁻¹	5.0 L ha ⁻¹
Dimethenamid-P	K3	-	K3	*	1008 g ha ⁻¹	1.4 L ha ⁻¹
Pethoxamid	K4	-	K4	*	1200 g ha ⁻¹	2.0 L ha ⁻¹
Clomazone	K5	-	K5	*	96 g ha ⁻¹	0.2 L ha ⁻¹
Metobromuron	K6	-	K6	*	1500 g ha ⁻¹	3.0 L ha ⁻¹
Metribuzin	K7	-	K7		330 g ha ⁻¹	0.55 L ha ⁻¹
Post-emergence treatments						
Diflufenican	-	-	K8	*	125 g ha ⁻¹	0.25 L ha ⁻¹
Flumioxazin		K1	K9	*	30 g ha ⁻¹	0.06 kg ha ⁻¹
Chlorotoluron	-	-	K21	*	125 g ha ⁻¹	0.25 L ha ⁻¹
Imazamox	K8	-	K20		40 g ha ⁻¹	1.0 L ha ⁻¹
Chlorotoluron	-	K2	K10	*	1400 g ha ⁻¹	2.8 L ha ⁻¹
Halauxifen-methyl	-	K3	K11	*	1.3 g ha ⁻¹	0.4 L ha ⁻¹
	-	K4	K12		1.6 g ha ⁻¹	0.5 L ha ⁻¹
	-	K5	K13		1.9 g ha ⁻¹	0.6 L ha ⁻¹
Halauxifen-methyl + Picloram	-	K6	K14		2.5 + 12 g ha ⁻¹	0.25 L ha ⁻¹
Halauxifen-methyl + Picloram	-	K7	K15		5 + 24 g ha ⁻¹	0.5 L ha ⁻¹
Prosulfocarb	-	K8	K16		2000 g ha ⁻¹	2.5 L ha ⁻¹
Carfentrazone-ethyl	-	K9	K17	*	14 g ha ⁻¹	35.0 g ha ⁻¹
Sulfoszulfuron	-	K10	K18	*	9.8 g ha ⁻¹	13.0 g ha ⁻¹
Sulfoszulfuron	-	K11	K19		12.8 g ha ⁻¹	17.0 g ha ⁻¹
Control	K9	K12	K22		—	—

The * marks the active substances selected after preliminary testing

In the 2022 experimental year, three herbicide treatments were applied pre-emergence in the common vetch stand in the days following sowing. The post-emergence treatments were applied 32 days after sowing, when the plants were at the BBCH 30 phenological stage, corresponding to the beginning of stem elongation. At this time, a total of five post-emergence treatments were applied, the detailed data of which are presented in *Table 3*.

In the 2023 experimental year, only post-emergence treatments were applied in common vetch. These treatments were carried out 38 days after sowing, when the crop stand was at the BBCH 37 phenological stage. At this developmental stage, seven visibly elongated internodes were observed on the plants, which provided an appropriate phenological basis for evaluating the selectivity of the post-emergence active ingredients and their effects on the crop. During the experiments, the active ingredients flumioxazin and chlorotoluron were tested at two different doses. In addition, the effects of active ingredient combinations were also examined in this year, and the evaluation of an adjuvant was also included in the experiments.

In the 2024 experimental year, the pre-emergence treatments were applied in the common vetch stand on the third day after sowing, on 21 March. The post-emergence treatments were carried out on 29 April, 42 days after sowing. At this time, the plants were at the BBCH 38 developmental stage, meaning that eight visibly elongated internodes could be observed. During the post-emergence treatments, the active ingredients flumioxazin and chlorotoluron were again applied at two doses. Similarly to the previous year, the examination of different active ingredient combinations was continued, along with the testing of adjuvant application.

In the 2025 growing season, the pre-emergence treatments were applied on the day of sowing. The post-emergence treatments were applied 36 days after sowing, when common vetch was at the BBCH 36 phenological stage. At this developmental stage, six visibly elongated internodes were observed on the plants. The timing of the treatments in this year was also adjusted to the current developmental stage of the crop, allowing a comparable evaluation of the active ingredients and treatment methods examined.

Table 3. Common vetch experiment treatment codes, active substances, time of application, doses of active substances and herbicide application rate
(Nyíregyháza, 2022-2025)

Active substances	Treatment codes				Active substance dose	Herbicide application rate
	2022	2023	2024	2025		
Pre-emergence treatments						
Pendimethalin	K1	-	K1	*	2275 g ha ⁻¹	5.0 L ha ⁻¹
S-metolachlor	K2	-	K2		1344 g ha ⁻¹	1.4 L ha ⁻¹
Flumioxazin	K3	-	K3	*	30 g ha ⁻¹	0.06 kg ha ⁻¹
Clomazone	-	-	K4	*	96 g ha ⁻¹	0.2 L ha ⁻¹
Metribuzin	-	-	K5	*	330 g ha ⁻¹	0.55 L ha ⁻¹
Post-emergence treatments						
Flumioxazin	-	K1	K6	*	30 g ha ⁻¹	0.06 kg ha ⁻¹
	-	K2	K7	*	40 g ha ⁻¹	0.08 kg ha ⁻¹
Chlorotoluron	-	K3	K8	*	1400 g ha ⁻¹	2.8 L ha ⁻¹
	-	K4	K9	*	1500 g ha ⁻¹	3.0 L ha ⁻¹
Clopyralid + Picloram	-	K5	K10		80 + 20 g ha ⁻¹	0.3 L ha ⁻¹
Metazachlor + Quinmerac	-	K6	K11	*	666 + 166 g ha ⁻¹	2.0 L ha ⁻¹
	-	K7	K12	*	749 + 187 g ha ⁻¹	2.25 L ha ⁻¹
MCPB	-	K8	K13		876 g ha ⁻¹	2.0 L ha ⁻¹
	-	K9	K14		1314 g ha ⁻¹	3.0 L ha ⁻¹
Triflusaluron-methyl	-	K10	-		10 g ha ⁻¹	20.0 g ha ⁻¹
Triflusaluron-methyl + ethoxylated isodecyl alcohol	-	K11	-		10 g ha ⁻¹	20.0 g ha ⁻¹
Sulfosulfuron	-	K12	K15		7.5 g ha ⁻¹	10.0 g ha ⁻¹
Thifensulfuron-methyl	-	K13	K16		7.5 g ha ⁻¹	15.0 g ha ⁻¹
Thifensulfuron-methyl + ethoxylated isodecyl alcohol	-	K14	K17		7.5 g ha ⁻¹	15.0 g ha ⁻¹
Bentazon	K4	-	-		960 g ha ⁻¹	2.0 L ha ⁻¹
	-	K15	K18		720 g ha ⁻¹	1.5 L ha ⁻¹
Imazamox	K5	-	-		24 g ha ⁻¹	0.6 Lha ⁻¹
	K6	-	K19		32 g ha ⁻¹	0.8 L ha ⁻¹
	K7	-	-		40 g ha ⁻¹	1.0 L ha ⁻¹
	K8	-	-		48 g ha ⁻¹	1.2 L ha ⁻¹
Control	K9	K16	K20		-	-

The * marks the active substances selected after preliminary testing

In the 2023 experimental year, the pre-emergence active ingredients were applied immediately after sowing in buckwheat. In the two weeks following the pre-emergence treatments, 18 mm of precipitation was recorded. The post-emergence treatments were applied 21 days after sowing, when buckwheat was between the BBCH 14 and BBCH 50 phenological stages, with approximately five fully developed leaves (Table 4).

In 2024, the pre-emergence active ingredients were applied on 9 May, one day after sowing. In the two weeks following treatment, 26.9 mm of precipitation was measured. The post-emergence treatments were applied on 3 June, 25 days after sowing, at the BBCH 60 phenological stage, when the first flowers had already opened in the buckwheat stand. In 2025, the post-emergence treatments were applied 37 days after sowing, at the beginning of flowering (BBCH 62).

Table 4. Buckwheat experiment treatment codes, active substances, time of application, doses of active substances and herbicide application rate

(Nyíregyháza, 2023-2025)

Active substances	Treatment codes			Active substance dose	Herbicide application rate
	2023	2024	2025		
Pre-emergence treatments					
Flurochloridone	K1	K1		500 g ha ⁻¹	2.0 L ha ⁻¹
S-metolachlor	K2	K2		1344 g ha ⁻¹	1.4 L ha ⁻¹
Post-emergence treatments					
2,4-D	K3	K3		600 g ha ⁻¹	1.0 L ha ⁻¹
Clopyralid	K4	K4	*	120 g ha ⁻¹	0.2 L ha ⁻¹
Halauxifen-methyl	K5	K5		2.5 g ha ⁻¹	0.8 L ha ⁻¹
	K6	K6		3.1 g ha ⁻¹	1.0 L ha ⁻¹
Halauxifen-methyl + Picloram	K7	K7		2.5 + 12 g ha ⁻¹	0.25 L ha ⁻¹
	K8	K8		5 + 24 g ha ⁻¹	0.5 L ha ⁻¹
Halauxifen-methyl + Clopyralid	K9	K9	*	3.8 + 90 g ha ⁻¹	0.75 L ha ⁻¹
	K10	K10	*	5 + 120 g ha ⁻¹	1.0 L ha ⁻¹
Metribuzin	K11	K11	*	180 g ha ⁻¹	0.3 L ha ⁻¹
	K12	K12	*	240 g ha ⁻¹	0.4 L ha ⁻¹
Sulfosulforon	K13	K13		6.0 g ha ⁻¹	8.0 g ha ⁻¹
	K14	K14		7.5 g ha ⁻¹	10.0 g ha ⁻¹
Triflurosulfuron-methyl	K15	-		12.5 g ha ⁻¹	25.0 g ha ⁻¹
	K16	K15		7.5 g ha ⁻¹	15.0 g ha ⁻¹
Mesotrione	K17	K16	*	120 g ha ⁻¹	0.25 L ha ⁻¹
Terbutylazine + Mesotrione + S-metolachlor	K18	K17		500 + 150 + 1500 g ha ⁻¹	4.0 L ha ⁻¹
control	K19	K18		-	-

The * marks the active substances selected after preliminary testing

The During the phytotoxicity assessment, herbicide active ingredients with different mechanisms of action were applied in hairy vetch in order to evaluate their effects on the crop and their selectivity. The first experiment was originally sown in November 2023; however, the stand was winter-killed as a result of unfavorable winter conditions. Therefore, the experiment was re-sown in March 2024. The pre-emergence treatments were applied on the first day after sowing. During the two weeks following sowing, a total of 12 mm of precipitation was recorded. The post-emergence treatments were applied 44 days after sowing, when the hairy vetch stand was at the BBCH 34 phenological stage. At this developmental stage, four visibly elongated internodes were observed on the plants. Thus, the timing of the post-emergence treatments was adjusted to the current developmental stage of the crop, enabling a comparative evaluation of the phytotoxic effects of active ingredients with different mechanisms of action. The detailed data of the treatments are presented in *Table 5*.

The second experiment was sown in October 2024. In this case, the pre-emergence treatments were also applied on the first day after sowing, and the timing of the treatments corresponded to the technology used in the first experimental year. However, no precipitation occurred during the two weeks following application, which can be considered an unfavorable condition for the activation and efficacy of pre-emergence active ingredients in the soil. Nevertheless, the phytotoxic effects of the treatments were more pronounced in the second experimental year than in the first experiment. This suggests that crop sensitivity and the response to the treatments were not determined exclusively by precipitation conditions after application, but may also have been influenced by factors related to autumn sowing, overwintering, and the different environmental and stand development conditions. In the 2025 experimental year, the post-emergence treatments were applied 155 days after sowing. At the time of application, the hairy vetch stand was at the BBCH 19 phenological stage, when nine or more leaves had developed on the plants.

Table 5. Hairy vetch experiment treatment codes, active substances, time of application, doses of active substances and herbicide application rate

(Nyíregyháza, 2024-2025)

Active substances	Treatment codes		Active substance dose	Herbicide application rate
	2024	2025		
Pre-emergence treatments				
Pendimethalin	K1	K1	2275 g ha ⁻¹	5.0 L ha ⁻¹
Flumioxazin	K2	K2	30 g ha ⁻¹	0.06 kg ha ⁻¹
Flumioxazin	K3	K3	40 g ha ⁻¹	0.08 kg ha ⁻¹
Clomazone	K4	K4	96 g ha ⁻¹	0.2 L ha ⁻¹
Metribuzin	K5	K5	180 g ha ⁻¹	0.3 L ha ⁻¹
Metribuzin	K6	K6	240 g ha ⁻¹	0.4 L ha ⁻¹
Diflufenican	-	K7	125 g ha ⁻¹	0.25 L ha ⁻¹
Post-emergence treatments				
Flumioxazin	K7	K8	30 g ha ⁻¹	0.06 kg ha ⁻¹
Flumioxazin	K8	K9	40 g ha ⁻¹	0.08 kg ha ⁻¹
Chlorotoluron	K9	K10	1400 g ha ⁻¹	2.8 L ha ⁻¹
Clopyralid + Picloram	K10	-	80 + 20 g ha ⁻¹	0.3 L ha ⁻¹
Metazachlor	-	K11	750 g ha ⁻¹	1.5 L ha ⁻¹
Metazachlor + Quinmerac	K11	K12	666 + 166 g ha ⁻¹	2.0 L ha ⁻¹
Metazachlor + Quinmerac	K12	K13	749 + 187 g ha ⁻¹	2.25 L ha ⁻¹
Imazamox	K13	K14	80 g ha ⁻¹	2.0 L ha ⁻¹
Halauxifen-methyl	K14	K15	1.6 g ha ⁻¹	0.5 L ha ⁻¹
Halauxifen-methyl	K15	K16	1.9 g ha ⁻¹	0.6 L ha ⁻¹
Halauxifen-methyl + Clopyralid	K16	K17	5 + 120 g ha ⁻¹	1.0 L ha ⁻¹
Bentazon	K17	K18	1440 g ha ⁻¹	3.0 L ha ⁻¹
Diflufenican	-	K19	125 g ha ⁻¹	0.25 L ha ⁻¹
Control	K18	K20	–	–

During the growing seasons, plant development was documented photographically. Normalized Difference Vegetation Index (NDVI) data were collected, and phytotoxicity assessments were also performed.

NDVI measurements were taken each year using a Trimble GreenSeeker HCS-100 handheld sensor. Higher NDVI values indicate healthier plants, whereas lower values

suggest some form of plant stress or problem (Bolaños et al., 2020). The NDVI values obtained from device-based measurements reflect not only the health status of the vegetation but also the extent of the phytotoxic effects of herbicides on the plants.

The severity of symptoms was determined according to the herbicide assessment methodology of Dancza (2004). To allow statistical evaluation, individual scale values were assigned to the percentage values, and this scaling method was used to determine the severity of symptoms and for subsequent assessments. On the scale, a value of 1 indicated the absence of symptoms (a constant value assigned to the control plants), whereas a value of 9 corresponded to complete plant death.

The seed samples were cleaned using a Westrup Kamas laboratory seed-cleaning machine. The seed-cleaning equipment separates and removes unwanted materials through a combination of sieves of different sizes, mechanical shaking, and directed airflow. Using the machine, various undesirable plant materials were removed (broken seeds, flat seeds, dry plant residues, and weed seeds). The weight of the seed samples at harvest was recorded, then the weight after cleaning was documented, and these data were used to calculate proportional values. This procedure was carried out in every growing season. In the 2024 experimental year, common vetch developed uniformly during the growing season; however, did not produce seed probably due to heat stress, and therefore no seed cleaning was carried out. In 2025, no seeds developed after pod formation. Because buckwheat produced only a minimal seed yield, mechanical cleaning was not possible, therefore, in 2024 the seeds were cleaned using a hand sieve. Hairy vetch was resown in spring 2024, but because it is mainly an autumn-sown crop, spring sowing did not support seed production, so no seed yield developed in the plots. Nevertheless, the crop stand was suitable for phytotoxicity assessment. In 2025, similarly to common vetch, no seeds developed in the pods of hairy vetch either.

3. RESULTS

3.1. NDVI, phytotoxicity and yield results of herbicide experiments in sweet white lupine (2022-2025), focusing on the active substances selected in the final year.

Table 6 summarizes the NDVI and phytotoxicity results of the small-plot field experiments in sweet white lupine conducted in 2022-2025, focusing on the active substances selected in the final year. The 2025 final assessment primarily included those active ingredients that, based on the results of previous years, had proven promising or worthy of further investigation. In 2025, plants treated with the pre-emergence active ingredients flumioxazin, pendimethalin, dimethenamid-P, pethoxamid, clomazone, and metobromuron showed NDVI values close to those of the control, similarly to the NDVI results observed in previous growing seasons. Based on the visual phytotoxicity assessment, no symptoms, or only mild symptoms, were observed on the crop plants. For diflufenican applied both pre- and post-emergence, data are available from two years. Based on the results, no significant difference was observed compared with the control in terms of either NDVI values or phytotoxicity symptoms.

In 2025, the plants were treated post-emergence with flumioxazin, chlorotoluron, halauxifen-methyl, carfentrazone-ethyl, sulfosulfuron and diflufenican. The post-emergence treatments affected the vegetative status of the sweet white lupine stand to varying degrees. Plants treated with flumioxazin, chlorotoluron and carfentrazone-ethyl showed a significant negative difference in NDVI values compared with the control plants. In line with this, damage symptoms were also observed in these treatments during the visual phytotoxicity assessment.

Table 6. NDVI and phytotoxicity results of herbicide experiments in sweet white lupine
(Nyíregyháza, 2022-2025)

	Application rate	NDVI value				Phytotoxicity value			
Treatments		2022	2023	2024	2025	2022	2023	2024	2025
Pre-emergence treatments									
Flumioxazin	0.06 kg ha ⁻¹	0.508 ^{ab}	-	0.773 ^a	0.667 ^{abc}	1.47 ^c	-	1.00 ^f	1.00 ^c
Pendimethalin	5.0 L ha ⁻¹	0.552 ^a	-	0.743 ^{abc}	0.658 ^{abc}	1.08 ^c	-	1.42 ^f	1.05 ^c
Dimethenamid-P	1.4 L ha ⁻¹	0.500 ^{ab}	-	0.750 ^{abc}	0.649 ^a	1.64 ^c	-	1.17 ^f	1.00 ^c
Pethoxamid	2.0 L ha ⁻¹	0.553 ^a	-	0.734 ^{abc}	0.679 ^{abc}	1.03 ^c	-	1.42 ^f	1.00 ^c
Clomazone	0.2 L ha ⁻¹	0.559 ^a	-	0.758 ^a	0.671 ^{abc}	1.31 ^c	-	1.33 ^f	1.00 ^c
Metobromuron	3.0 L ha ⁻¹	0.549 ^a	-	0.752 ^{ab}	0.651 ^{abc}	1.25 ^c	-	1.08 ^f	1.15 ^c
Diflufenican	0.25 L ha ⁻¹	-	-	0.738 ^{abc}	0.648 ^{abc}	-	-	1.83 ^f	1.00 ^c
Post-emergence treatments									
Flumioxazin	0.06 kg ha ⁻¹	-	0.755 ^b	0.742 ^{abc}	0.488 ^e	-	5.00 ^{bc}	2.08 ^{ef}	5.70 ^a
Chlorotoluron	2.8 L ha ⁻¹	-	0.760 ^b	0.719 ^{abc}	0.566 ^d	-	5.13 ^b	1.92 ^f	2.90 ^b
Halauxifen-methyl	0.4 L ha ⁻¹	-	0.783 ^{ab}	0.724 ^{abc}	0.634 ^{bc}	-	1.38 ^{ef}	2.25 ^{ef}	1.00 ^c
Carfentrazone-ethyl	35.0 g ha ⁻¹	-	0.780 ^{ab}	0.752 ^{ab}	0.564 ^d	-	4.00 ^{cd}	1.17 ^f	3.30 ^b
Sulfosulfuron	13.0 g ha ⁻¹	-	0.788 ^{ab}	0.725 ^{abc}	0.630 ^c	-	2.25 ^e	1.33 ^f	1.80 ^c
Diflufenican	0.25 L ha ⁻¹	-	-	0.751 ^{abc}	0.645 ^{abc}	-	-	1.50 ^f	1.75 ^c
Control	-	0.556 ^a	0.800 ^a	0.769 ^a	0.674 ^{ab}	1.00 ^c	1.00 ^f	1.00 ^f	1.00 ^c

Different letters indicate significant differences among treatment means according to Duncan's test ($p < 0.05$).

Seed yield of plants treated pre-emergence with flumioxazin, pendimethalin, dimethenamid-P, pethoxamid, clomazone, metobromuron and diflufenican did not differ significantly from that of the control in any of the growing seasons studied.

In 2025, the seed yield of plants treated post-emergence with flumioxazin differed significantly from that of the control plants in a negative direction. In 2025, the seed yield of plants treated with chlorotoluron and carfentrazone-ethyl showed a decreasing trend compared with the control. In 2025, the seed yield of plants treated with halauxifen-methyl, sulfosulfuron and diflufenican numerically exceeded the yield of the control plants (Table 7).

Table 7. Yield results of herbicide experiments in sweet white lupine
(Nyíregyháza, 2022-2025)

	Application rate	Yield results kg ha ⁻¹			
Treatments		2022	2023	2024	2025
Pre-emergence treatments					
Flumioxazin	0.06 kg ha ⁻¹	745 ^a	-	1847 ^a	1468 ^a
Pendimehtalin	5.0 L ha ⁻¹	822 ^a	-	1374 ^{ab}	1085 ^{ab}
Dimethenamid-P	1.4 L ha ⁻¹	767 ^a	-	1506 ^{ab}	1313 ^{ab}
Pethoxamid	2.0 L ha ⁻¹	770 ^a	-	1416 ^{ab}	1225 ^{ab}
Clomazone	0.2 L ha ⁻¹	812 ^a	-	1906 ^a	1247 ^{ab}
Metobromuron	3.0 L ha ⁻¹	732 ^a	-	1834 ^a	1237 ^{ab}
Diiflufenican	0.25 L ha ⁻¹	-	-	1540 ^{ab}	1257 ^{ab}
Post-emergence treatments					
Flumioxazin	0.06 kg ha ⁻¹	-	1113 ^a	1537 ^{ab}	446 ^c
Chlorotoluron	2.8 L ha ⁻¹	-	841 ^{ab}	1597 ^a	926 ^b
Halauxifen-methyl	0.4 L ha ⁻¹	-	1430 ^a	1691 ^a	1232 ^{ab}
Carfentrazone-ethyl	35.0 g ha ⁻¹	-	1323 ^a	1672 ^a	894 ^b
Sulfoszulfuron	13.0 g ha ⁻¹	-	1453 ^a	1447 ^{ab}	1194 ^b
Diiflufenican	0.25 L ha ⁻¹	-	-	1775 ^a	1176 ^b
Control	-	718 ^a	1085 ^a	1725 ^a	1172 ^b

Different letters indicate significant differences among treatment means according to Duncan's test ($p < 0.05$).

3.2. NDVI and phytotoxicity results of herbicide experiments in common vetch (2022-2025), focusing on the active substances selected in the final year

Table 8 summarizes the NDVI and phytotoxicity results of the small-plot field experiments in common vetch conducted in 2022–2025, focusing on the active substances selected in the final year. In 2025, the pre-emergence application of flumioxazin, clomazone and metribuzin did not cause phytotoxicity, which was also confirmed by the measured NDVI values. For plants treated with the aforementioned active substances, the previous results also showed values close to those of the control. An exception was the 2024 application of metribuzin, which showed a statistically significant difference; however, it still resulted only in a scale value indicating mild symptoms. Phytotoxicity values of plants treated with pendimethalin differed from the control during the growing seasons and indicated very slight to slight symptoms on the scale.

In 2025, the post-emergence application of flumioxazin and chlorotoluron caused significant phytotoxicity, which was also reflected in the NDVI values. In the previous growing seasons, phytotoxicity of varying intensity (milder to stronger) was also observed, however, its values remained below the scale values recorded in 2025. In 2025, the NDVI and phytotoxicity values of plants treated with the metazachlor + quinmerac active substance combination did not differ from those of the control plants. In the 2023 growing season, the treatments including the metazachlor + quinmerac combination generally caused higher phytotoxicity, however, no differences from the control were observed in the other measured parameters.

Table 8. NDVI and phytotoxicity results of herbicide experiments in common vetch (Nyíregyháza, 2022-2025)

	Application rate	NDVI value				Phytotoxicity value			
Treatments		2022	2023	2024	2025	2022	2023	2024	2025
Pre-emergence treatments									
Pendimethalin	5.0 L ha ⁻¹	0.521 ^a	-	0.820 ^{bc}	0.685 ^b	3.19 ^{ab}	-	1.94 ^{ef}	2.31 ^d
Flumioxazin	0.06 kg ha ⁻¹	0.570 ^a	-	0.855 ^a	0.729 ^{ab}	1.81 ^c	-	1.06 ^g	1.44 ^{de}
Clomazone	0.2 L ha ⁻¹	-	-	0.857 ^a	0.743 ^{ab}	-	-	1.00 ^g	1.38 ^{de}
Metribuzin	0.55 L ha ⁻¹	-	-	0.845 ^{ab}	0.732 ^{ab}	-	-	1.94 ^{ef}	1.19 ^e
Post-emergence treatments									
Flumioxazin	0.06 kg ha ⁻¹	-	0.843 ^{ab}	0.848 ^{ab}	0.623 ^c	-	3.88 ^{ef}	1.81 ^{efg}	5.00 ^c
Flumioxazin	0.08 kg ha ⁻¹	-	0.853 ^a	0.850 ^{ab}	0.528 ^d	-	4.00 ^{ef}	1.50 ^{fg}	7.06 ^a
Chlorotoluron	2.8 L ha ⁻¹	-	0.858 ^a	0.826 ^{abc}	0.690 ^b	-	3.75 ^{ef}	3.63 ^d	4.69 ^c
Chlorotoluron	3.0 L ha ⁻¹	-	0.853 ^a	0.840 ^{abc}	0.603 ^c	-	2.38 ^g	2.38 ^e	6.06 ^b
Metazachlor + Quinmerac	2.0 L ha ⁻¹	-	0.858 ^a	0.854 ^a	0.758 ^a	-	4.63 ^{def}	1.00 ^g	1.71 ^{de}
Metazachlor + Quinmerac	2.25 L ha ⁻¹	-	0.860 ^a	0.859 ^a	0.739 ^{ab}	-	3.38 ^{fg}	1.00 ^g	1.56 ^{de}
Control	-	0.523 ^a	0.865 ^a	0.853 ^{ab}	0.730 ^{ab}	1.00 ^c	1.00 ^h	1.00 ^g	1.00 ^e

Different letters indicate significant differences among treatment means according to Duncan's test ($p < 0.05$).

3.3. NDVI, phytotoxicity and yield results of herbicide experiments in buckwheat (2023–2025), focusing on the active substances selected in the final year

Table 9 summarizes the NDVI and phytotoxicity results of the small-plot field experiments in buckwheat conducted in 2023-2025, focusing on the active substances selected in the final year. In none of the years did the NDVI and phytotoxicity values of plants treated with the active substance clopyralid differ negatively from those of the control plants. For plants treated with the active substance mesotrione, clear phytotoxic symptoms were recorded only in 2023, while in the examined growing seasons no significant differences in the measured parameters were observed compared with the control. Plants treated with different doses of the halauxifen-methyl + clopyralid active substance combination showed phytotoxicity symptoms to varying degrees in 2024 and 2025. The lower dose of the active substance metribuzin caused clear phytotoxic symptoms only in 2024, whereas the higher dose resulted in damage of varying intensity (from slight to severe) in two growing seasons.

Table 9. NDVI and phytotoxicity results of herbicide experiments in buckwheat (Nyíregyháza, 2023-2025)

	Application rate	NDVI value			Phytotoxicity value		
Treatments		2023	2024	2025	2023	2024	2025
Post-emergence treatments							
Clopyralid	0.2 L ha ⁻¹	0.768 ^a	0.770 ^{cdef}	0.643 ^a	2.40 ^{ef}	1.00 ^h	2.13 ^{bc}
Mesotrione	0.25 L ha ⁻¹	0.728 ^{ab}	0.752 ^{efg}	0.633 ^a	4.30 ^{bcd}	1.00 ^h	1.94 ^{bc}
Halauxifen-methyl + Clopyralid	0.75 L ha ⁻¹	0.763 ^a	0.799 ^{abc}	0.666 ^a	1.80 ^{ef}	4.00 ^f	3.0 ^{ab}
Halauxifen-methyl + Clopyralid	1.0 L ha ⁻¹	0.803 ^a	0.808 ^{ab}	0.688 ^a	1.80 ^{ef}	4.33 ^{ef}	4.31 ^a
Metribuzin	0.3 L ha ⁻¹	0.795 ^a	0.787 ^{abcde}	0.637 ^a	2.8 ^{def}	4.33 ^{ef}	2.5 ^{bc}
Metribuzin	0.4 L ha ⁻¹	0.785 ^a	0.758 ^{defg}	0.658 ^a	3.3 ^{cde}	5.75 ^{cd}	1.69 ^{bc}
Control	-	0.793 ^a	0.734 ^g	0.643 ^a	1.00 ^f	1.00 ^h	1.00 ^c

Different letters indicate significant differences among treatment means according to Duncan's test ($p < 0.05$).

Seed yields did not differ significantly from the control in any growing season; only trend-like deviations were observed for treatments with clopyralid, mesotrione, the halauxifen-methyl + clopyralid combination (at different doses), and metribuzin (at different doses) (Table 10).

Table 10. Yield results of herbicide experiments in buckwheat (Nyíregyháza, 2023-2025)

	Application rate	Yield results kg ha ⁻¹		
Treatments		2023	2024	2025
Clopyralid	0.2 L ha ⁻¹	563 ^{ab}	106 ^{abcd}	688 ^a
Mesotrione	0.25 L ha ⁻¹	533 ^{ab}	123 ^{abc}	507 ^{ab}
Halauxifen-methyl + Clopyralid	0.75 L ha ⁻¹	437 ^{ab}	99 ^{abcd}	491 ^{ab}
Halauxifen-methyl + Clopyralid	1.0 L ha ⁻¹	533 ^{ab}	94 ^{bcd}	513 ^{ab}
Metribuzin	0.3 L ha ⁻¹	580 ^{ab}	169 ^a	638 ^{ab}
Metribuzin	0.4 L ha ⁻¹	603 ^{ab}	115 ^{abc}	631 ^{ab}
Control	-	613 ^{ab}	155 ^{ab}	524 ^{ab}

Different letters indicate significant differences among treatment means according to Duncan's test ($p < 0.05$).

3.4. NDVI and phytotoxicity results of herbicide experiments in hairy vetch in the 2024-2025 experimental years

Table 11 summarizes the NDVI and phytotoxicity results of the small-plot field experiments in hairy vetch conducted in 2024-2025, focusing on the active substances selected in the final year. In both years, the phytotoxicity values of the pendimethalin-treated plants were higher than those of the control, indicating a stronger phytotoxic effect. In 2024, they caused mild symptoms, whereas in 2025 they resulted in very severe symptoms, which were also reflected in the NDVI values. At the lower dose of flumioxazin (0.06 kg ha⁻¹), phytotoxicity values did not differ from those of the control. Plants treated with the active substance clomazone showed no phytotoxic symptoms in 2024; however, in 2025 severe damage was observed, which was also confirmed by the NDVI results. Over the past two years, plants treated with the lower dose of the active substance metribuzin (0.3 L ha⁻¹) showed higher NDVI values and lower phytotoxicity values than those treated with the higher dose (0.4 L ha⁻¹). In 2025, the active substance diflufenican treated plants did not differ from the control in NDVI or phytotoxicity values.

Post-emergence application of the flumioxazin at different doses (0.06 kg ha⁻¹ and 0.08 kg ha⁻¹) caused injury in both years. NDVI values of plants treated with the active substance chlorotoluron decreased compared with the control, which was also reflected in the phytotoxicity values. In 2024, the clopyralid + picloram active substance

combination caused severe damage; the active substances were not applied in 2025. Phytotoxicity values of plants treated with the metazachlor + quinmerac combination (2 and 2.25 L ha⁻¹) did not differ from those of the control, as the treatment induced only very slight symptoms. In 2024, the NDVI and phytotoxicity values of plants treated with the active substance imazamox did not differ from those of the control. In 2025, lower NDVI values were recorded, and the treated plants also showed phytotoxicity values that were significantly higher than those of the control. Plants treated with the active substance halauxifen-methyl (0.5 and 0.6 L ha⁻¹) showed significant phytotoxicity in both years, and their NDVI values were lower than those of the control. Bentazon caused no statistically significant differences in NDVI or phytotoxicity compared with the control, while post-emergence diflufenican caused mild but non-significant symptoms.

Table 11. NDVI and phytotoxicity results of herbicide experiments in hairy vetch (Nyíregyháza, 2024-2025)

Treatments	Application rate	NDVI value		Phytotoxicty value	
		2024	2025	2024	2025
Pre-emergence treatments					
Pendimethalin	5.0 L ha ⁻¹	0.694 ^{cd}	0.285 ⁱ	3.05 ^{ef}	8.25 ^{ab}
Flumioxazin	0.06 kg ha ⁻¹	0.759 ^{ab}	0.585 ^{abcd}	1.05 ^g	2.17 ^{efgh}
Flumioxazin	0.08 kg ha ⁻¹	0.767 ^a	0.529 ^{de}	1.00 ^g	3.17 ^{ef}
Clomazone	0.2 L ha ⁻¹	0.766 ^a	0.393 ^{fgh}	1.20 ^g	6.83 ^{bcd}
Metribuzin	0.3 L ha ⁻¹	0.765 ^a	0.623 ^{abc}	1.20 ^g	1.50 ^{gh}
Metribuzin	0.4 L ha ⁻¹	0.750 ^{abc}	0.562 ^{bcd}	1.65 ^g	3.42 ^e
Diflufenican	0.25 L ha ⁻¹	-	0.591 ^{abcd}	-	2.08 ^{efgh}
Post-emergence treatments					
Flumioxazin	0.06 kg ha ⁻¹	0.615 ^{ef}	0.378 ^{gh}	5.65 ^{cd}	6.17 ^d
Flumioxazin	0.08 kg ha ⁻¹	0.658 ^{de}	0.350 ^{hi}	5.20 ^d	6.67 ^{cd}
Chlorortoluron	2.8 L ha ⁻¹	0.703 ^{bcd}	0.405 ^{fgh}	3.45 ^e	6.67 ^{cd}
Clopyralid + Picloram	0.3 L ha ⁻¹	0.321 ^h	-	7.60 ^{ab}	-
Metazachlor	1.5 L ha ⁻¹	-	0.440 ^{fg}	-	6.17 ^d
Metazachlor + Quinmerac	2.0 L ha ⁻¹	0.719 ^{abc}	0.541 ^{cde}	2.15 ^{fg}	2.17 ^{efgh}
Metazachlor + Quinmerac	2.25 L ha ⁻¹	0.765 ^a	0.625 ^{ab}	1.60 ^g	1.58 ^{fgh}
Imazamox	2.0 L ha ⁻¹	0.754 ^{ab}	0.541 ^{cde}	1.85 ^g	2.83 ^{efg}
Halauxifen-methyl	0.5 L ha ⁻¹	0.497 ^g	0.470 ^{ef}	6.85 ^{ab}	5.83 ^d
Halauxifen-methyl	0.6 L ha ⁻¹	0.565 ^f	0.385 ^{gh}	6.50 ^{bc}	7.78 ^{abc}
Halauxifen-methyl + Clopyralid	1.0 L ha ⁻¹	0.275 ^h	0.282 ⁱ	7.85 ^a	9.00 ^a
Bentazon	3.0 L ha ⁻¹	0.781 ^a	0.619 ^{abc}	1.25 ^g	1.53 ^{gh}
Diflufenican	0.25 L ha ⁻¹	-	0.592 ^{abcd}	-	2.58 ^{efgh}
Control	-	0.779 ^a	0.649 ^a	1 ^g	1.00 ^h

Different letters indicate significant differences among treatment means according to Duncan's test ($p < 0.05$).

4. NEW CONTRIBUTIONS TO ACADEMIC KNOWLEDGE

1. In white lupine (*Lupinus albus* L.), common vetch (*Vicia sativa* L.), hairy vetch (*Vicia villosa* Roth.), and buckwheat (*Fagopyrum esculentum* Moench.), I demonstrated through **correlation test** using Spearman's rho that **NDVI data** can serve as an effective tool for the **quantitative assessment of vegetation condition and the effects of herbicides**.
2. In my experiment, I demonstrated a **significant positive** relationship between **NDVI values** and seed yield, whereas a **significant negative** relationship was observed between **phytotoxicity values** and **seed yield**.
3. Based on the comparison of the investigated crops, **white lupine (*Lupinus albus* L.) can be considered the least herbicide-sensitive species**, as it had the highest proportion of favourably evaluated treatments among both the pre-emergence and post-emergence applications. However, only some of the pre-emergence treatments: **flumioxazin** (0.06 kg ha⁻¹, 500 g kg⁻¹), **pendimethalin** (5.0 L ha⁻¹, 455 g L⁻¹), **dimethenamid-P** (1.4 L ha⁻¹, 720 g L⁻¹), **pethoxamid** (2.0 L ha⁻¹, 600 g L⁻¹), **clomazone** (0.2 L ha⁻¹, 480 g L⁻¹), and **metobromuron** (3.0 L ha⁻¹, 500 g L⁻¹) **could be classified as fully selective**.
4. **Based on the yield results, flumioxazin** (0.06 kg ha⁻¹; 500 g kg⁻¹) and **clomazone** (0.2 L ha⁻¹; 480 g L⁻¹) proved to be the most effective treatments in white lupine (*Lupinus albus* L.).
5. In comparison with international literature data, we confirmed that pre-emergence **flumioxazin** can be safely applied in **white lupine and common vetch**, while **pre-emergence pendimethalin** can be safely used in **white lupine**. However, based on our results, **post-emergence imazamox** in **white lupine**, **pre-emergence fluorochloridone** in **buckwheat**, and **pre-emergence pendimethalin** in **hairy vetch** exhibited more adverse phytotoxic effects than those reported in the literature.

5. PRACTICAL USE OF THE RESULTS

1. For **white lupine**, I **recommend** the following active ingredients for **registration for pre-emergence application** at the specified rates: flumioxazin (0.06 kg ha^{-1} ; 500 g kg^{-1}), pendimethalin (5.0 L ha^{-1} ; 455 g L^{-1}), dimethenamid-P (1.4 L ha^{-1} ; 720 g L^{-1}), pethoxamid (2.0 L ha^{-1} ; 600 g L^{-1}), clomazone (0.2 L ha^{-1} ; 480 g L^{-1}), and metobromuron (3.0 L ha^{-1} ; 500 g L^{-1}). For **pre-emergence application**, I **recommend** further **testing** of diflufenican at a rate of 0.25 L ha^{-1} (500 g L^{-1}). For **post-emergence application**, I **recommend** further **testing** of the following active ingredients at the specified rates: halauxifen-methyl (0.4 L ha^{-1} ; 3 g L^{-1}), sulfosulfuron (13.0 g ha^{-1} ; 750 g kg^{-1}), and diflufenican (0.25 L ha^{-1} ; 500 g L^{-1}). I **do not recommend** further **pre-emergence testing** of metribuzin at a rate of 0.55 L ha^{-1} (600 g L^{-1}). For **post-emergence application**, I **do not recommend** further **testing** of the following active ingredients at the specified rates: flumioxazin (0.06 kg ha^{-1} ; 500 g kg^{-1}), chlorotoluron (2.8 L ha^{-1} ; 500 g L^{-1}), imazamox (1.0 L ha^{-1} ; 40 g L^{-1}), halauxifen-methyl + picloram (0.25 and 0.5 L ha^{-1} ; $10 + 48 \text{ g L}^{-1}$), carfentrazone-ethyl (35.0 g ha^{-1} ; 400 g kg^{-1}), prosulfocarb (2.5 L ha^{-1} ; 800 g L^{-1}), and the higher dose of sulfosulfuron (17.0 g ha^{-1} ; 750 g kg^{-1}).
2. For **common vetch**, I **recommend** further **pre-emergence testing** of the following active ingredients at the specified rates: flumioxazin (0.06 kg ha^{-1} ; 500 g kg^{-1}), clomazone (0.2 L ha^{-1} ; 480 g L^{-1}), and metribuzin (0.55 L ha^{-1} ; 600 g L^{-1}). For **post-emergence application**, I **recommend** further **testing** of metazachlor + quinmerac at rates of 2.0 and 2.25 L ha^{-1} ($333 + 83 \text{ g L}^{-1}$). I **do not recommend** further **pre-emergence testing** of pendimethalin at a rate of 5.0 L ha^{-1} (455 g L^{-1}). For **post-emergence application**, I **do not recommend** further **testing** of the following active ingredients at the specified rates: flumioxazin (0.06 and 0.08 kg ha^{-1} ; 500 g kg^{-1}), chlorotoluron (2.8 and 3.0 L ha^{-1} ; 500 g L^{-1}), bentazone (1.5 and 2.0 L ha^{-1} ; 480 g L^{-1}), clopyralid + picloram (0.3 L ha^{-1} ; $267 + 67 \text{ g L}^{-1}$), MCPB (2.0 and 3.0 L ha^{-1} ; 400 g L^{-1}), sulfosulfuron (10.0 g ha^{-1} ; 750 g kg^{-1}), triflurosulfuron-methyl (20.0 g ha^{-1} ; 500 g kg^{-1}), thifensulfuron-methyl (15.0 g ha^{-1} ; 500 g kg^{-1}), and imazamox ($0.6, 0.8, 1.0$, and 1.2 L ha^{-1} ; 40 g L^{-1}).

3. For **buckwheat**, I **recommend** further **post-emergence testing** of the following active ingredients at the specified rates: clopyralid (0.2 L ha^{-1} ; 600 g L^{-1}), mesotrione (0.25 L ha^{-1} ; 100 g L^{-1}), and metribuzin (0.3 L ha^{-1} ; 600 g L^{-1}). I do **not recommend** further **pre-emergence testing** of fluorochloridone at a rate of 2.0 L ha^{-1} (250 g L^{-1}). For **post-emergence** application, I **do not recommend** further **testing** of the following active ingredients at the specified rates: 2,4-D (1.0 L ha^{-1} ; 600 g L^{-1}), halauxifen-methyl (0.8 and 1.0 L ha^{-1} ; 3 g L^{-1}), halauxifen-methyl + picloram (0.25 and 0.5 L ha^{-1} ; $10 + 48 \text{ g L}^{-1}$), halauxifen-methyl + clopyralid (0.75 and 1.0 L ha^{-1} ; $5 + 120 \text{ g L}^{-1}$), metribuzin (0.4 L ha^{-1} ; 600 g L^{-1}), sulfosulfuron (8.0 and 10.0 g ha^{-1} ; 750 g kg^{-1}), thifensulfuron-methyl (15.0 g ha^{-1} ; 500 g kg^{-1}), and terbuthylazine + mesotrione + S-metolachlor (4.0 L ha^{-1} ; $125 + 37.5 + 375 \text{ g L}^{-1}$).
4. For **hairy vetch**, I **recommend** further **pre-emergence testing** of the following active ingredients at the specified rates: flumioxazin (0.06 and 0.08 kg ha^{-1} ; 500 g kg^{-1}), metribuzin (0.3 and 0.4 L ha^{-1} ; 600 g L^{-1}), and diflufenican (1.5 L ha^{-1} ; 500 g L^{-1}). I **do not recommend** further **pre-emergence testing** of clomazone (0.2 L ha^{-1} ; 480 g L^{-1}) or pendimethalin (5.0 L ha^{-1} ; 455 g L^{-1}). For **post-emergence application**, I **recommend** further **testing** of the following active ingredients at the specified rates: metazachlor + quinmerac (2.0 and 2.25 L ha^{-1} ; $333 + 83 \text{ g L}^{-1}$), imazamox (2.0 L ha^{-1} ; 40 g L^{-1}), bentazone (3.0 L ha^{-1} ; 480 g L^{-1}), and diflufenican (0.25 L ha^{-1} ; 500 g L^{-1}). I **do not recommend** further **post-emergence testing** of the following active ingredients at the specified rates: flumioxazin (0.06 and 0.08 kg ha^{-1} ; 500 g kg^{-1}), chlorotoluron (2.8 L ha^{-1} ; 500 g L^{-1}), clopyralid + picloram (0.3 L ha^{-1} ; $267 + 67 \text{ g L}^{-1}$), halauxifen-methyl (0.5 and 0.6 L ha^{-1} ; 3 g L^{-1}), and halauxifen-methyl + clopyralid (1.0 L ha^{-1} ; $5 + 120 \text{ g L}^{-1}$).
5. We found that, **following seed cleaning, higher levels of yield contamination** comprising weed seeds and green and dry plant residues generally originated from plots where herbicide treatments damaged the crop and caused **stand thinning**, thereby **promoting weed proliferation** and the development of less pure crop stands.

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Letöltve: 2021. 09.18.

7. PUBLICATIONS ON THE SUBJECT OF THE DISSERTATION



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Subject: PhD Publication List

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Doctoral School: Kálmán Kerpely Doctoral School
MTMT ID: 10079390

List of publications related to the dissertation

Hungarian book chapters (1)

1. **Juhász, C.:** Néhány alternatív növényfaj (csillagfűrt, tavaszi bükköny, szöszös bükköny, pohánka) szerepe a hazai mezőgazdaságban.
In: A hatékonyabb agráriumért : Tudományos Szakkollégiumi Kiadvány / Rácz Dalma (szerk.), Debreceni Egyetem MÉK, Debrecen, 13-20, 2021.

Hungarian scientific articles in Hungarian journals (1)

2. **Juhász, C.,** Zsombik, L.: Különböző gombaölő szerek hatása a fehérvirágú csillagfűrt (*Lupinus albus* L.) és a tavaszi bükköny (*Vicia sativa* L.) termésmennyiségére és magfertőzöttségére. *Növénytermelés*. 73 (1), 1-18, 2024. ISSN: 0546-8191.

Foreign language scientific articles in Hungarian journals (1)

3. **Juhász, C.,** Pál, V., Zsombik, L.: Results of weed surveys in greening plants. *Agrártud. Közl.* 1 (1), 53-57, 2023. ISSN: 1587-1282.
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4. **Juhász, C.,** Mendlerné Drienyovszki, N., Magyarné Tábori, K., Zsombik, L.: Evaluation of Chemical Weed-Control Strategies for Common Vetch (*Vicia sativa* L.) and Sweet White Lupine (*Lupinus albus* L.) Under Field Conditions. *Agronomy*. 15, 1-30, 2025. EISSN: 2073-4395.
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5. **Juhász, C.,** Mendlerné Drienyovszki, N., Magyarné Tábori, K., Radócz, L., Zsombik, L.: Effect of Different Herbicides on Development and Productivity of Sweet White Lupine (*Lupinus albus* L.). *Agronomy-Basel*. 14 (3), 1-19, 2024. EISSN: 2073-4395.
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6. **Juhász, C.**, Abido, W. A. E., Hadházy, Á., Pál, V., Radócz, L., Zsombik, L.: Effect of Seeding Rates of the Mixture of Rye (*Secale cereale* L.) and Hairy Vetch (*Vicia villosa* Roth.) on Rye Yield.
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DOI: <http://dx.doi.org/10.21608/jpp.2023.188098.1205>
7. **Juhász, C.**, Hadházy, Á., Abido, W. A. E., Pál, V., Zsombik, L.: Impact of some herbicides on the growth and the yield of common vetch (*Vicia sativa* L.).
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8. **Juhász, C.**, Nagy, M., Mendlerné Drienyovszki, N., Magyarné Tábori, K., Zsombik, L.: Effect of postemergently applied herbicides on the development of sweet white lupine (*Lupinus albus* L.).
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9. **Juhász, C.**, Zsombik, L.: Tavaszi búkkönyben (*Vicia Sativa* L.) végzett gyomirtószeres kezelés okozta változások nyomon követése multispektrális képalkotó drón használatával.
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10. **Juhász, C.**, Zsombik, L.: Különböző gyomirtószeres hatása a szőszös búkköny (*Vicia Villosa* Roth.) fejlődésére.
In: 39. Óvári Tudományos Nap : Konferencia : "Az agrár-, élelmiszer- és vidékgazdaság kihívásai" : Absztrakt kötet. Szerk.: Molnár Zoltán, Némethné Wurm Katalin, Széchenyi István Egyetem Albert Kázmér Mosonmagyaróvári Kar, Mosonmagyaróvár, 93, 2023. ISBN: 9786156443243
11. **Juhász, C.**, Pál, V., Zsombik, L.: Zöldítő növényekben végzett gyomfelvételezés eredményei.
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Foreign language abstracts (4)

12. **Juhász, C.**, Magyarné Tábori, K., Mendlerné Drienyovszki, N., Zsombik, L.: An overview of the herbicide options for one of the alternative pseudocereals-buckwheat (*Fagopyrum esculentum* Moench).
In: Proceedings of the Plants 2025: From Seeds to Food Security, Barcelona, 31 March - 2 April 2025. Ed.: Dilantha Fernando, MDPI, Basel, 1, 2025.





13. **Juhász, C.**, Zsombik, L.: Assessment of phytotoxic effects of pre- and post-emergence herbicides on buckwheat (*Fagopyrum esculentum* Moench.) to identify selective weed control options.
In: Abstract Book of the 4th European Buckwheat Symposium - Buckwheat: Innovations in Agriculture, Breeding, Nutrition and Sustainability. Szerk.: Magyar-Tábori Katalin, Mendlér-Drienyovszki Nóra, Hanász Alexandra, [n.n.], Nyíregyháza, , 2025. ISBN: 9789634907350
14. **Juhász, C.**, Zsombik, L.: Results of the fungicide test in sweet white lupine (*Lupinus albus* L.) and common vetch (*Vicia sativa* L.).
In: XXVII. Tavaszi Szél Konferencia 2024 : Absztrakt kötet. Szerk.: Hajdú Péter, Doktoranduszok Országos Szövetsége, Budapest, 625, 2024. ISBN: 9786156457523
15. **Juhász, C.**, Mendlerné Drienyovszki, N., Zsombik, L.: Analysis of the effects of different herbicides on the development of buckwheat (*Fagopyrum Esculentum* Moench).
In: The 15th International Symposium on Buckwheat: Buckwheat for health /ed. Grażyna Hołubowicz-Kliza, Institute of Soil Science and Plant Cultivation- State Research Institute, Pulawy, 59-60, 2023. ISBN: 9788375623987

List of other publications

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16. Zsigrai, G., Balling, P., **Juhász, C.**: A Teleki 5C és a Kober 125 AA hatása a Furmint T85-ös klón fejlődésére.
In: Az elmúlt évek kutatásai a Tokaji Borvidéken, 2017-2018.. Szerk.: Bihari Zoltán, Tokaji Kutatóintézet Nonprofit Kft., Tarcál, 19-25, 2018. ISBN: 9786150023007

Hungarian scientific articles in Hungarian journals (4)

17. Zsigrai, G., **Juhász, C.**: Különböző ökológiai K- és Mn-lombtrágya készítmények hatásának összehasonlító vizsgálata a Tokaji Borvidéken: - a fürttömeg, a mustminőség és a levélnyel kémiai összetételének változásai.
Szőlő-levél. 10 (5), 32-49, 2020. ISSN: 2677-1756.
18. Zsigrai, G., Bojtó, C., Horváth, É., **Juhász, C.**: Különböző ökológiai K- és Mn-lombtrágya készítmények hatásának összehasonlító vizsgálata a Tokaji Borvidéken: - klorofill fluoreszcencia és NDVI vizsgálatok eredményei.
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19. Zsigrai, G., Balling, P., **Juhász, C.**: A Teleki 5C és a Kober 125AA hatása a Furmint T85-ös klón fejlődésére.
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20. Riczu, P., **Juhász, C.**, Zsigrai, G.: Spektrális távérzékelés lehetősége szőlőültetvények kondíciójának térképezésére.
Szőlő-levél. 8 (5), 4-7, 2018. ISSN: 2677-1756.

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21. Radócz, L., **Juhász, C.**, Tamás, A., Illés, Á., Ragán, P., Radócz, L.: Multispectral UAV-Based Disease Identification Using Vegetation Indices for Maize Hybrids.
Agriculture-Basel. 14 (11), 1-15, 2024. EISSN: 2077-0472.
DOI: <http://dx.doi.org/10.3390/agriculture14112002>
IF: 3.6
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DOI: <http://dx.doi.org/10.21608/JPP.2021.207289>

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23. **Juhász, C.**: A táblán belüli talajheterogenitások szőlészeti jelentőségének hagyományos és spektrális módszerekkel történő vizsgálata eltérő alanyokra oltott furmint ültetvényekben.
In: XXXIV. Országos Tudományos Diákköri Konferencia. Agrártudományi Szekció. Előadás kivonatok. Szerk.: Juhász Csaba; Juhász Lajos; Gyüre Péter; Vári Erzsébet (szerkesztők, Debreceni Egyetem Mezőgazdaság-, Élelmiszertudományi és Környezetgazdálkodási Kar, Debrecen, 164, 2019. ISBN: 9789634900788
24. **Juhász, C.**: A talajadottságok és az alany szőlő vegetatív fejlődésre gyakorolt hatásának vizsgálata spektrális módszerrel = The examination of the impact of soil conditions and grape rootstock to the vegetation development with spectral methods.
In: "VII. Kerpely Kálmán Szakmai Napok : A Gyakorlatorientált Oktatásért" c. konferencia kiadvány. Kiadta: a Debreceni Egyetem Kerpely Kálmán Szakkollégium, Debreceni Egyetem Kerpely Kálmán Szakkollégium, Debrecen, 22-23, 2017. ISBN: 9789634739593

Total IF of journals (all publications): 10,4

Total IF of journals (publications related to the dissertation): 6,8

The Candidate's publication data submitted to the Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.



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